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Estimation of personal exposure to ambient nicotine in daily environment

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Summary. To evaluate the actual exposure level of nonsmokers to environmental tobacco smoke (ETS) in their daily life, the exposure level of ambient nicotine was measured with a nicotine personal monitor carried by a nonsmoker. Average exposure levels of nicotine, even in such smoky places as cars, coffee shops and pubs, were less than 45 μg/m³. As a result of all-day monitoring, the highest amount of nicotine inhaled in a day was estimated, in this study, to be up to 310 μg, equivalent to actively smoking 0.31 ordinary cigarettes.

Key words: Passive smoking – Nicotine personal monitor – Environmental tobacco smoke (ETS) – Exposure level

Introduction

Several epidemiological studies have suggested a relationship between passive smoking and an increased risk of lung cancer [12]. However, one major dispute about these studies is the lack of measurement of actual exposure to ETS [7, 10]. When studying the health effects of passive smoking, it is important to determine the actual exposure level of nonsmokers to ETS in daily life.

The exposure level to ETS has previously been evaluated by measuring concentration of such constituents as nicotine, cotinine and COHb [e.g. 4–6, 8] in body fluids. Meanwhile, the authors have recently developed a convenient personal nicotine monitor to estimate the exposure level of nonsmokers to ETS in the living places [9]. In the present work, by using the personal monitor carried by nonsmokers, exposure levels of nicotine in various daily environments and daily lives were measured.

Materials and methods

The personal monitor consists of a sampler tube (Pyrex glass; 12-cm-long, 6-mm-i.d.) and a small sampling pump (about 3x MP-* Scientific Inc., Model 808) fitted with a means of

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measuring sample volume. The personal monitor can be carried conveniently by a person throughout a sampling period. The sampler tube contains 450 mg of Uniport-S (60 to 80 mesh; Gas-kuro Kogyo Co.) coated with 4 wt% of silicone OV-17 as a nicotine absorbent. Prior to the coating, the acidity of Uniport-S was adjusted with KOH to 30 to 70 μmol/g when calculated according to the n-butylamine titration method [11] using methyl red as an indicator. The sampler tube packed with the absorbent was aged at 310°C for 15 h by passing nitrogen gas through the tube at 40 ml/min.

Ambient nicotine was collected on the sampler tube by drawing air through the tube at a flow rate of 40 ml/min for a period of 1 to 8 h. After collection, 5 μl of n-propanol solution containing 400 ng of 7-methylquinoline (7-MQ) was injected into the sampler tube as an internal standard. Then the sampler tube was placed in a cylindrical furnace heated to 280°C and connected to a gas chromatograph (GC) with a nitrogen-sensitive detector. By passing the carrier gas through the sampler tube, collected nicotine and 7-MQ were desorbed and directly transferred onto the GC column (2 m × 3 mm i.d. glass column) packed with Chromosorb W (AW-DMCS, 30 to 60 mesh) coated with 10 wt% PEG-20M and 2 wt% KOH. The thermal desorption was allowed to continue for 8 min, while the column temperature was held at 70°C in order to trap and concentrate both nicotine and 7-MQ on the top of the column. During the first 3 min of the thermal desorption, a small amount of ammonia vapor was added three times into the carrier gas by bubbling the carrier gas through 35 wt% ammonia water for 6 s, once per min. The addition of ammonia vapor is effective on the thermal desorption of nicotine and 7-MQ against the acidic property of Uniport-S. After the thermal desorption time, the column temperature was programed to 185°C at 46°C/min and maintained at 185°C until completion of elution.

Both the collection and desorption efficiencies of nicotine were nearly 100% [9].

Results and discussion

Figure 1 shows the average and standard deviation of personal exposure to ambient nicotine in various places. The values in the offices, households and pubs are an average from an 8-h sampling period, and the remainder are from a 1-h sampling period. The "amount of nicotine inhaled" shown in this figure was estimated by multiplying the nicotine concentration by a respiration volume of 0.48 m^3/h. Then the "equivalent cigarettes smoked", which represent the level of passive smoking, can be obtained by dividing the "amount of nicotine inhaled" by the nicotine amount (1 mg) inhaled through active smoking from one ordinary cigarette.

The average exposure level of nicotine in three ventilated offices, A, B and C, was in the range of 5.9 to 19.8 μg/m^3. The nicotine inhaled is estimated to be in the range of about 2.8 to 9.5 μg/h. This value was calculated to be equivalent to the amount of nicotine inhaled through active smoking from 0.003 to 0.010 ordinary cigarettes/h.

Figure 2 shows the exposure levels measured over one week for three subjects, a, b and c at Office C with 72 m^2 of floor space. They were exposed to 3.0 to 10.2 μg/m^3 of nicotine in their ventilated office, where 28 to 48 cigarettes had been smoked daily. The exposure level of Subject a always showed the highest level, indicating that the actual exposure to ETS may differ with each subject, even in a small office.

Exposure levels in coffee shops, pubs and cars, naturally influenced by the number of cigarettes smoked and the ventilation conditions, showed relatively high values (Fig. 1). Average exposure level of nicotine in such places was in the

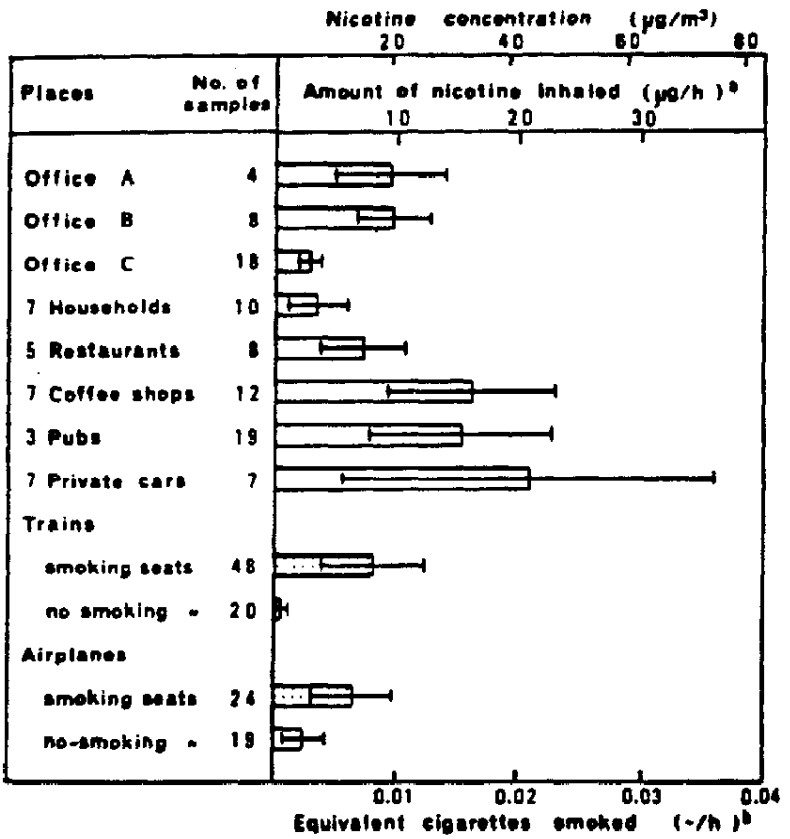

Fig. 1. Personal exposure to ambient nicotine in various environments. (a) Respiration volume was estimated to be 8 l/min; (b) Amount of nicotine in main stream smoke was estimated to be 1 mg/cig

range of 31.5 to 43.2 μg/m³. However, even in these instances, a nonsmoker does not inhale more than 50 μg/h of nicotine, equivalent to active smoking of about 0.05 cigarettes/h.

The average exposure levels in the smoking seats and the no-smoking seats of trains and airplanes were 16.7 and 1.3, and 13.5 and 5.3 μg/m³, respectively (Fig. 1). The highest nicotine exposure levels in the smoking seats of trains and airplanes were 48.6 and 28.8 μg/m³, respectively. However, these values were only equivalent to the amount of nicotine inhaled through active smoking from 0.023 and 0.014 cigarettes/h.

The exposure level to ETS depends on many factors, including room size and time of day. Further, people do not live in the same environment for 24 h.

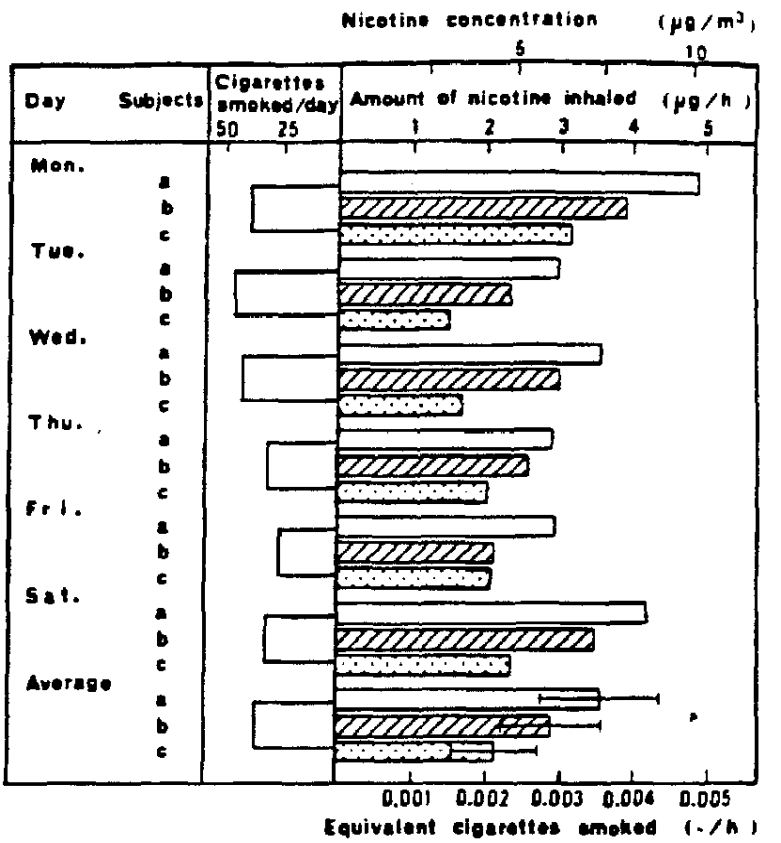

Fig. 2. Personal exposure of office workers to ambient nicotine in their office C

so the exposure level will differ with the behavior of individuals throughout the day.

Figure 3 shows the results of all-day monitoring of nicotine exposure for the nonsmoking subjects with or without an occupation in two cases where their families include and do not include a smoker. In this measurement, the sampler tube was exchanged every 8 h and the exposure level was monitored continuously for 1 to 6 d.

Nicotine inake is particularly high in subjects who are exposed to ETS at the workplace and at home. Some exposure to nicotine was also observed for many subjects without a smoker in their family. These results indicate that nonsmokers without a smoker in their family are also exposed to ETS when a

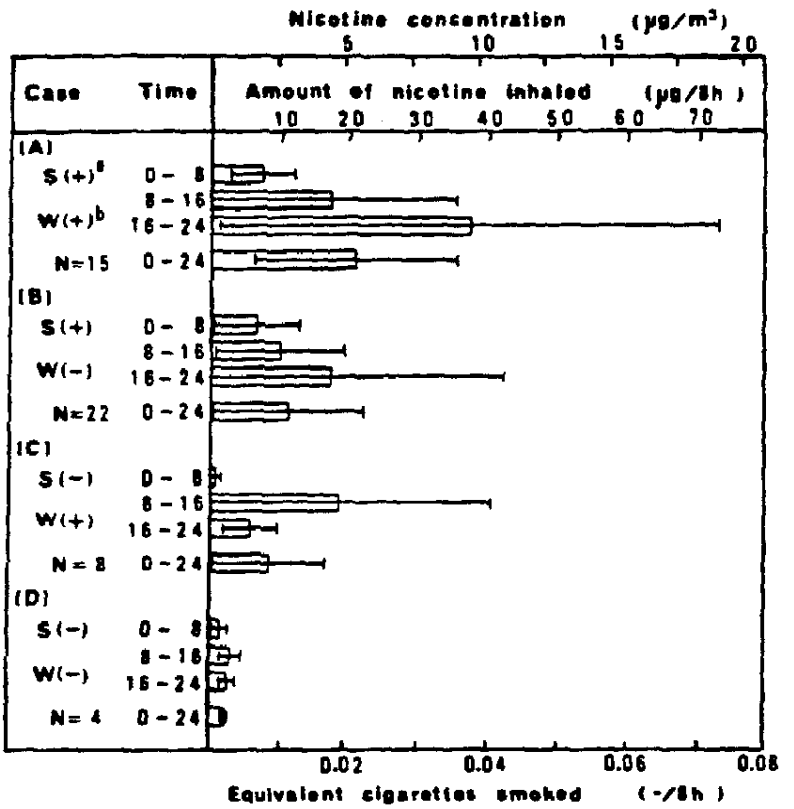

Fig. 3. Personal exposure to ambient nicotine over a period of 24 h in daily life. (a) S(+): with smoker in family. S(−): without smoker in family; (b) W(+): with occupation. W(−): without occupation

smoker visits, or when they go out. Therefore, it is impossible to evaluate their exposure to ETS based only on the smoking habits of their families.

In this all-day monitoring, the subject with the highest daily average of nicotine exposure was a housewife with a smoking husband. According to her report, she attended a party with him on that day. As a result, her daily average of exposure level amounted to 27.3 μg/m³, and the daily amount of nicotine inhaled was estimated to be up to 310 μg, equivalent to actively smoking 0.31 cigarettes.

Hinds and First [3], Bardre et al. [1] and First [2] reported that nicotine concentrations in various public places were in the range of 1 to 10.3, 20 to 50 and 2.7 to 30 μg/m³, respectively. Our result is consistent with theirs. Thus, the nicotine level in daily environments will rarely exceed 100 μg/m³. If a man stays

in a room with a 100 $\mu g/m^3$ nicotine level for 1 h, the amount of nicotine he will inhale is estimated only to be equivalent to that inhaled by actively smoking about 0.05 cigarettes.

Therefore, we can say that the amount of nicotine inhaled by a nonsmoker in his daily life is far smaller than that inhaled by a smoker through active smoking.

Nicotine is an excellent marker for ETS exposure because of its specifity for tobacco smoke. It is not necessarily clear, however, whether nicotine intake can provide the best quantitative estimation of the dose of ETS exposure or not. The composition of the sidestream smoke differs widely from that of mainstream smoke. The inhalation patterns in passive and active smoking are not comparable. The concentration of ambient nicotine decreases somewhat rapidly compared to that of other constituents of tobacco smoke, especially in a closed room without any ventilation. Consequently, in future it will be necessary to study quantitatively the relationship between nicotine, a vapor and particulate phase components of interest in ETS and biological markers such as cotinine to utilize nicotine fully as a quantitative marker of ETS exposure.

References

1. Badre R, Guillerm R, Abran N, Bourdin M, Dumas C (1978) Pollution atmosphérique par la fumée de tabac. Ann Pharmacol Fr 35:443–452
2. First MW (1984) Environmental tobacco smoke measurement: retrospect and prospect. Eur J Resp Dis [Suppl 133] 65:9–16
3. Hinds WC, First MW (1975) Concentration of nicotine and tobacco smoke in public places. New Engl J Med 292:844–845
4. Hoffmann D, Haley NJ, Adams JD, Brunnemann KD (1984) Tobacco sidestream smoke: uptake by nonsmokers. Prev Med 13:608–617
5. Jarvis MJ, Russell MAH, Feyerabend C (1983) Absorption of nicotine and carbon monoxide from passive smoking under natural conditions of exposure. Thorax 38:829–833
6. Jarvis MJ, Russell MAH, Feyerabend C, Eiser JR, Morgan M, Gammage P, Gray EM (1985) Passive exposure to tobacco smoke. Saliva cotinine concentrations in a representative population sample of nonsmoking school children. Br Med J 291:927–929
7. Lehnert G (Chairman), Garfinkel L, Hirayama T, Schmähl D, Uberla K, Wynder EL, Lee PN (1984) Roundtable discussion. Prev Med 13:730–746
8. Matsukura S, Taminato T, Kitano T, Seino Y, Hamada H, Uchihashi M, Nakajima H, Hirata Y (1984) Effect of environmental tobacco smoke on urinary cotinine excretion in nonsmokers. Evidence for passive smoking. New Engl J Med 311:828–832
9. Muramatsu M, Umemura S, Okada T, Tomita H (1984) Estimation of personal exposure to tobacco smoke with a newly developed nicotine personal monitor. Environ Res 35:218–227
10. Rylander R (1984) Environmental tobacco smoke and lung cancer. Eur J Resp Dis [Suppl 133] 65:127–133
11. Tamele MW (1950) Chemistry of the surface and the activity of alumina-silica cracking catalyst. Disc Faraday Soc 8:270–276
12. US Department of Health and Human Services, Public Health Service (1986) A report of the Surgeon General. The health consequences of involuntary smoking. DHHS Publication No. (CDC) 87–8398, pp 66–90

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